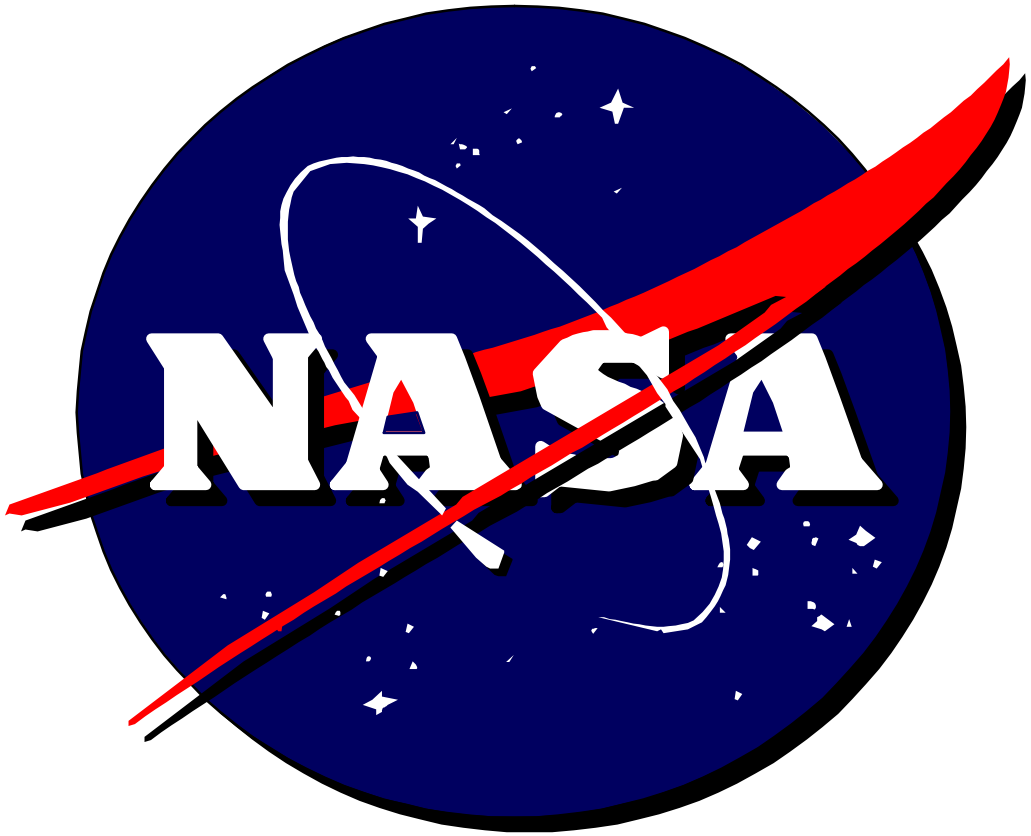
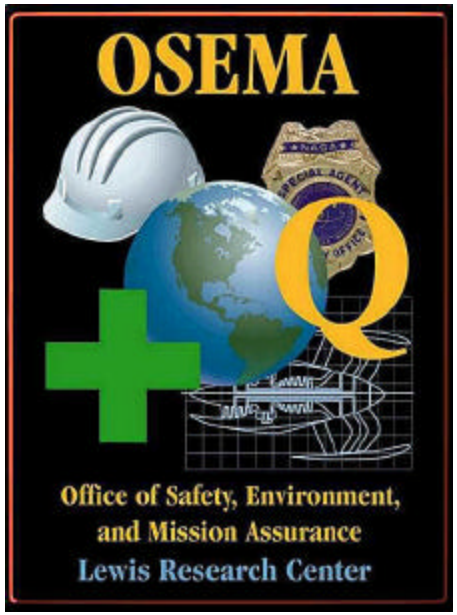
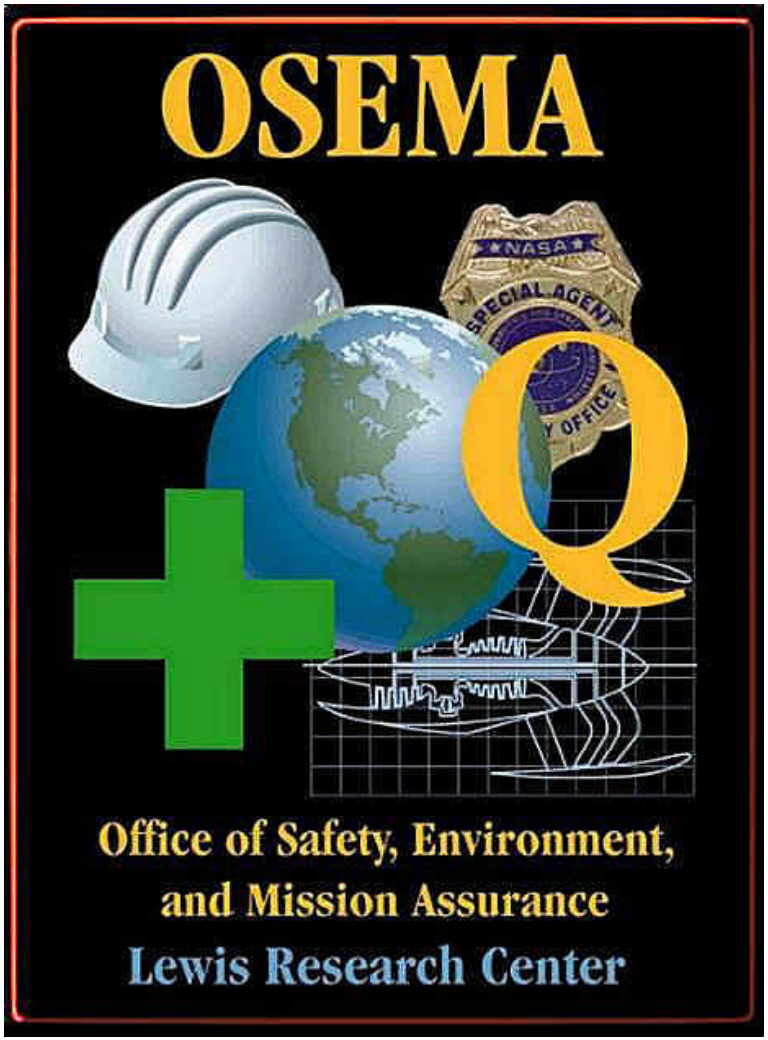
NASA, Lewis Research Center
Office of Safety, Environmental & Mission Assurance





DESIGN FOR RELIABILITY



WELCOME & COURSE OVERVIEW

Course Purpose/Objective

- **The *purpose* of this course is to introduce the concepts of Reliability and to provide an overview of Reliability Engineering methodology. Also the aim is to familiarize your project team members with the tools available for you to design for reliability on your project.**
- **The *objective* of this course is to instill in Engineers and Managers the benefits that the application of Reliability principals and practices can provide. These benefits include reduction in design and development cycles, improved quality and safety, increased product life, reduced maintenance and warrantee costs, and improved customer satisfaction.**

NASA CO-INSTRUCTORS

Vincent R. Lalli

NASA, Lewis Research Center
21000 Brookpark Road
M/S 501-4
Cleveland, Ohio 44135
(216) 433- 2354
(216) 433- 5270 fax
Vincent.R.Lalli@lerc.nasa.gov

Michael H. Packard

Raytheon E & C
2001 Aerospace Parkway
NYMA Building, M/S EBAS
Brook Park, Ohio 44112
(216) 977- 1490
(219) 977- 1494 fax
Michael.H.Packard@lerc.nasa.gov

CLASS INFORMATION

- **ATTENDANCE LIST (Class Roster)**
- **INTRODUCTION OF PARTICIPANTS (optional)**
- **INITIAL SURVEY**
- **FILL OUT NAME TAGS**

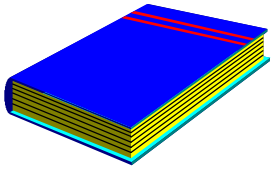
COURSE AGENDA/SCHEDULE

- **FOUR -- 7+hr sessions (Short Course 4hr sessions).**
- **10 minute each hour or as needed.**
- **IN CLASS PROBLEMS**
- **COURSE EVALUATION**
- ***HOMEWORK PROBLEMS (self-graded)***
- ***FINAL EXAM (self-graded)***
- **A certificate can be earned from the NASA Safety Training Center or NASA Lewis *after completion of homework and final*.**
- **Send completed work to: Vincent Lalli, M/S 501-4.**

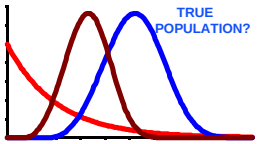
COURSE CONTENT

INTRODUCTION

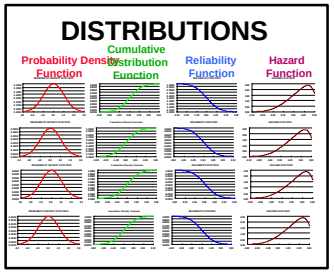
PRACTICES



MEASURE



?

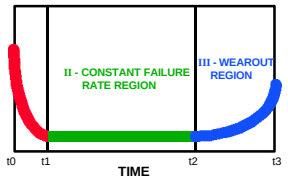


BASICS

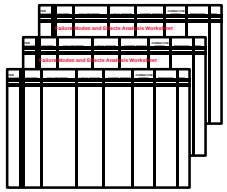
DR01-7

COURSE CONTENT+

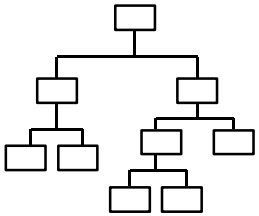
08 IMPROVING



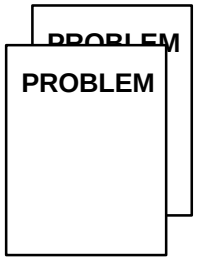
09 FMEA



10 FTA

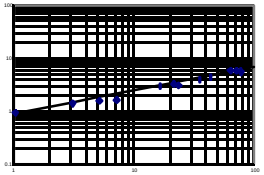


11 PROBLEMS



12 TESTING

13 GROWTH



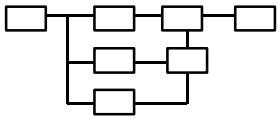
14 SOFTWARE

15 MANAGEMENT

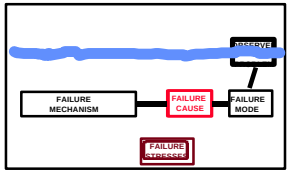
07 FAILURE DATA

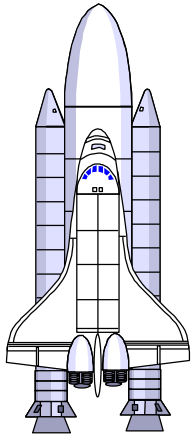
Mil 217

06 RBD



05 CONCEPTS





DR01-8

Class Material

- **Course Notes**
- **Nasa Technical Memorandum 4322, NASA Reliability Preferred Practices for Design and Test.**
- **NASA Reference Publication 1253, Reliability Training.**
- **Nasa Technical Memorandum 4628, Recommended Techniques for Effective Maintainability.**
- **Textbook II (optional)**

MODULE OBJECTIVES

- **These are key definitions, principles, tasks and procedures which the course participants need to understand and perform in order to have benefited from this course.**
- **They are listed at the beginning of each section and identify the main concepts of that section.**

INTRODUCTION TO RELIABILITY

- **Reliability is....**

  The *probability* that a system can perform its intended function....

  for a specified interval....

  under stated conditions.

OBJECTIVES:

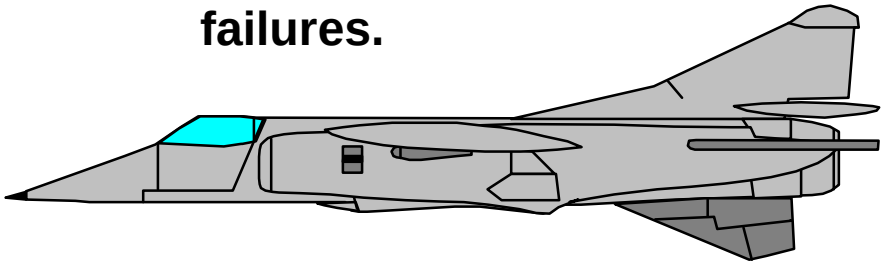
- **Be able to (answer):**
- **Why is Reliability Engineering needed? What are the benefits of Reliability Engineering?**
- **Define reliability and related terms.**
- **What are some of the key activities of Reliability Engineering? How do they support the project?**
- **Besides measuring reliability, what is even more important?**
- **Why do failures occur? What are the sources of failures?**
- **What is the relationship between safety, quality, reliability, maintainability and availability?**
- **Explain why the Reliability Engineering discipline developed.**

BENEFITS OF RELIABILITY PREDICTIONS

- INCREASE KNOWLEDGE OF CAUSES OF FAILURE
- ABILITY TO COMPLETE MISSION
- ACCURATE FORECAST OF SPARES, WARRANTY COSTS
- PEOPLE WANT SYSTEMS THAT WORK-- REFLECTS ON DESIGN AND MANUFACTURING ABILITY.
- REFLECTS ON COMPANY, ORGANIZATION.

WHY ARE SOME THINGS RELIABLE?

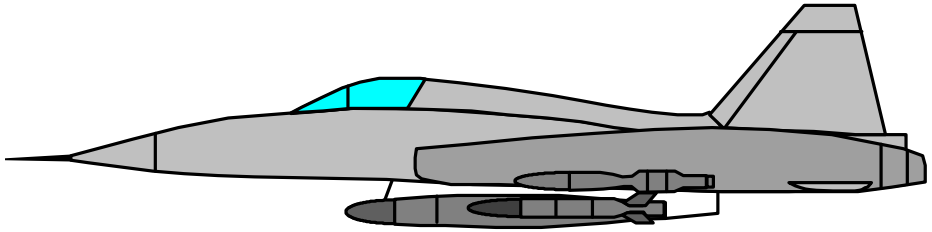
- **UNIT # 1**
  - **Frequent Break downs**
  - **Many minor component failures.**



UNIT # 2

-- No Major Break downs.

-- Few failures



RELIABILITY ANSWERS:

- **WHEN WILL SOMETHING FAIL?**
- **WHY DOES SOMETHING FAIL?**
- **HOW CAN IT BE IMPROVED?**

WHEN WILL SOMETHING FAIL?

- **The Reliability Engineer has a number of tools to analyze parts, components & systems:**

  Mean Time Between Failure (MTBF) calculations.

  Analysis of test data/history of operation.

  Reliability block diagrams.

  Other tools.

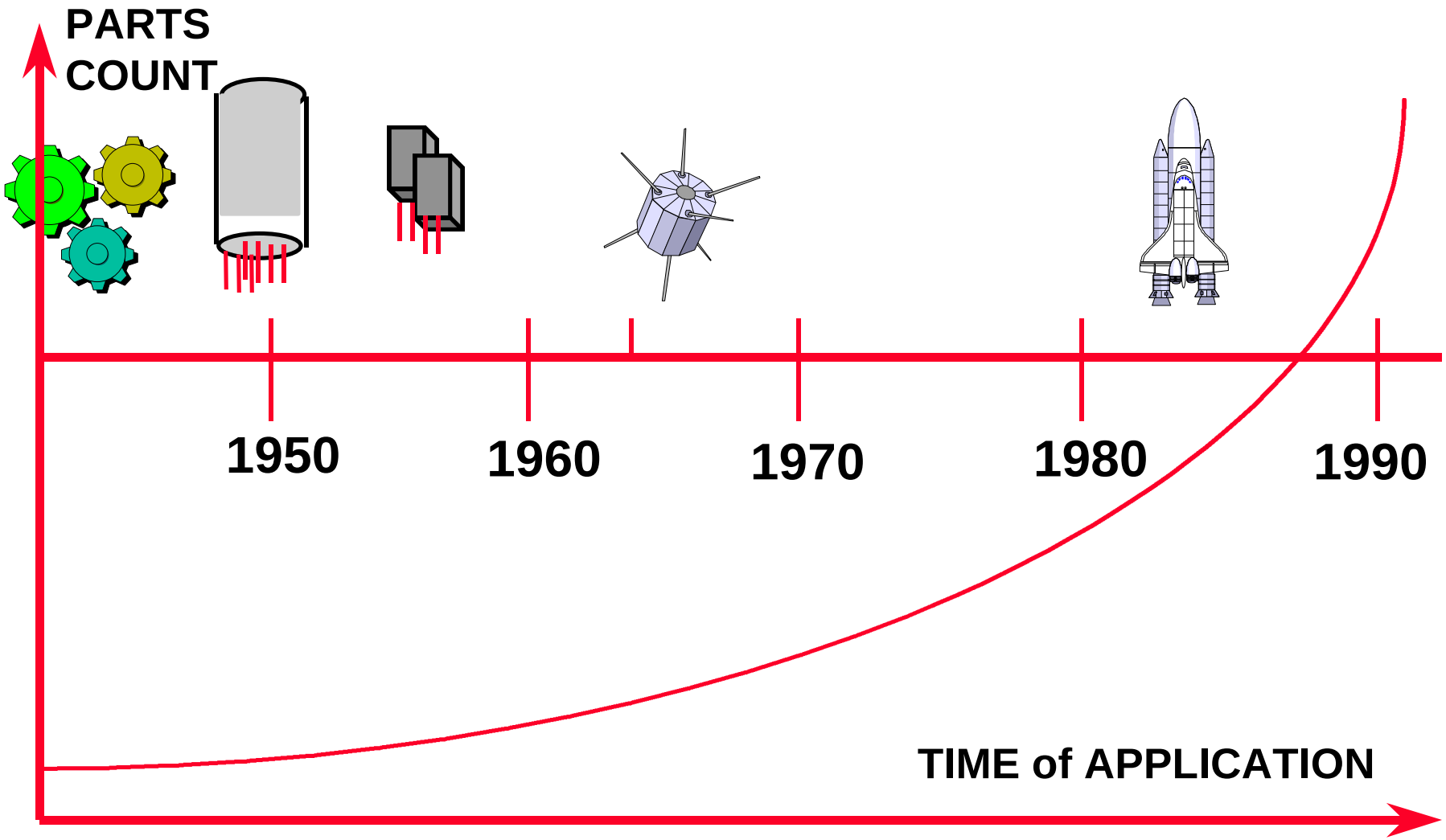
HOW CAN SOMETHING FAIL?

- **Failure Modes and Effects Analysis (FMEA)**
- **Fault Tree Analysis**
- **Sneak Circuit Analysis**
- **Worst Case Analysis**

HOW CAN IT BE IMPROVED?

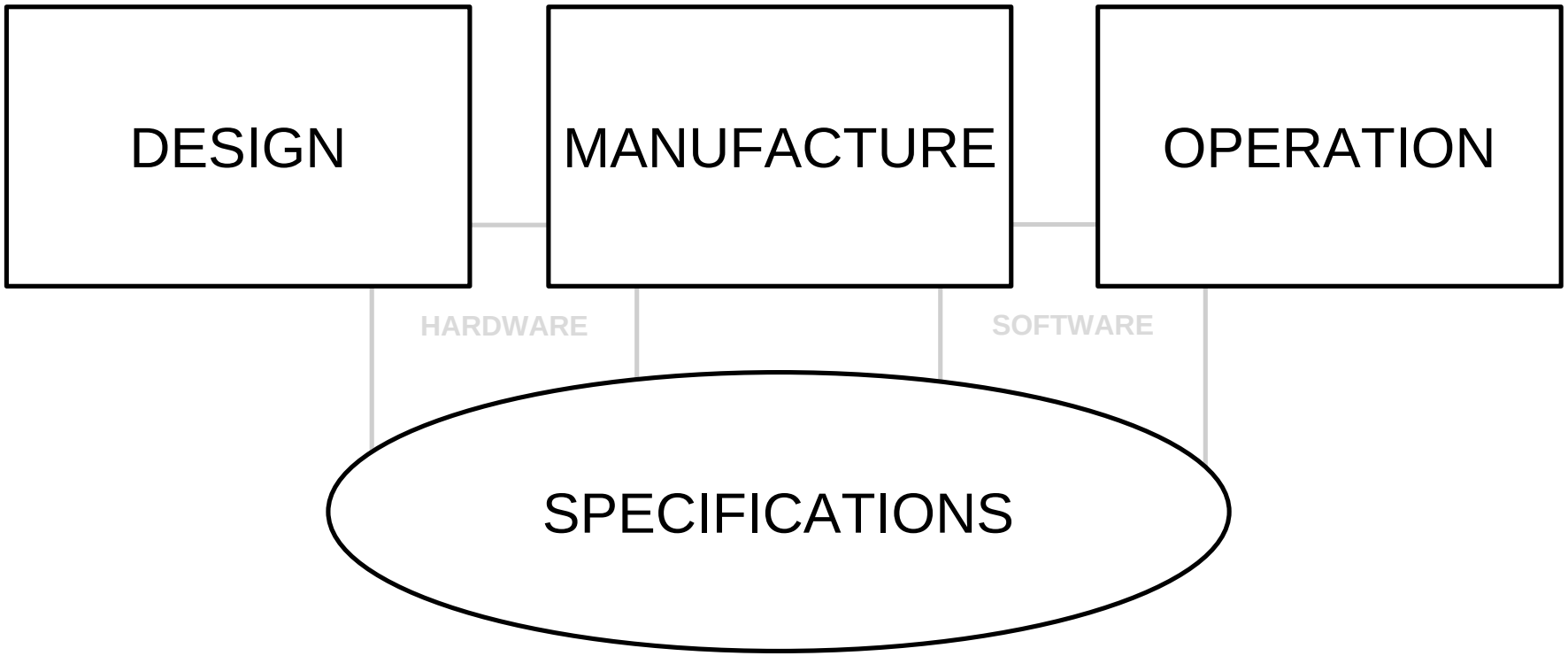
- **Failure Modes and Effects Analysis**
  - **Improving design to control critical single point failure modes.**
  - **Identifying critical items and improving them.**
- **Problem/Failure Reporting**
  - **Generating Histories of previous failures for future review on similar systems.**
  - **Reviewing anomalies for root causes of failures and verify corrective action.**
- **Testing and Analysis**
  - **Review of test data.**
  - **Test data application to new designs.**

HISTORY OF RELIABILITY



C> DR01-19

WHERE DO FAILURES COME FROM?

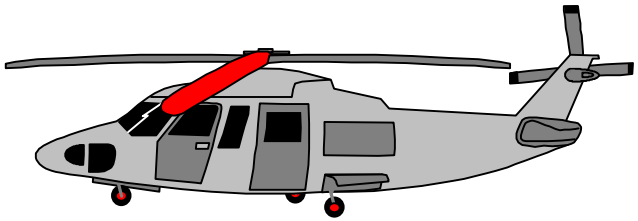


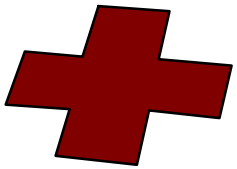
WHERE DO FAILURES COME FROM?

- **DESIGN**
  - TOLERANCES TO LOOSE (specifications)
  - IMPROPERLY UNDERSTOOD ENVIRONMENT.
  - INADEQUATE TESTING, DESIGN NOT CONFIRMED.
  - COMPONENT RELIABILITY NOT UNDERSTOOD.
- **MANUFACTURING**
  - MATERIAL SUBSTITUTIONS.
  - IMPROPER PROCESSES (MFG. AND ASSEMBLY).
  - CONTAMINATION.
  - MACHINE OPERATIVES NOT PROPERLY TRAINED.
  - IMPROPER MATERIAL TREATMENT
- **OPERATION**
  - LOADS EXCEED PREDICTED ENVIRONMENT.
  - NEW ENVIRONMENT (also storage).
  - POOR ERGONOMICS (human engineering)

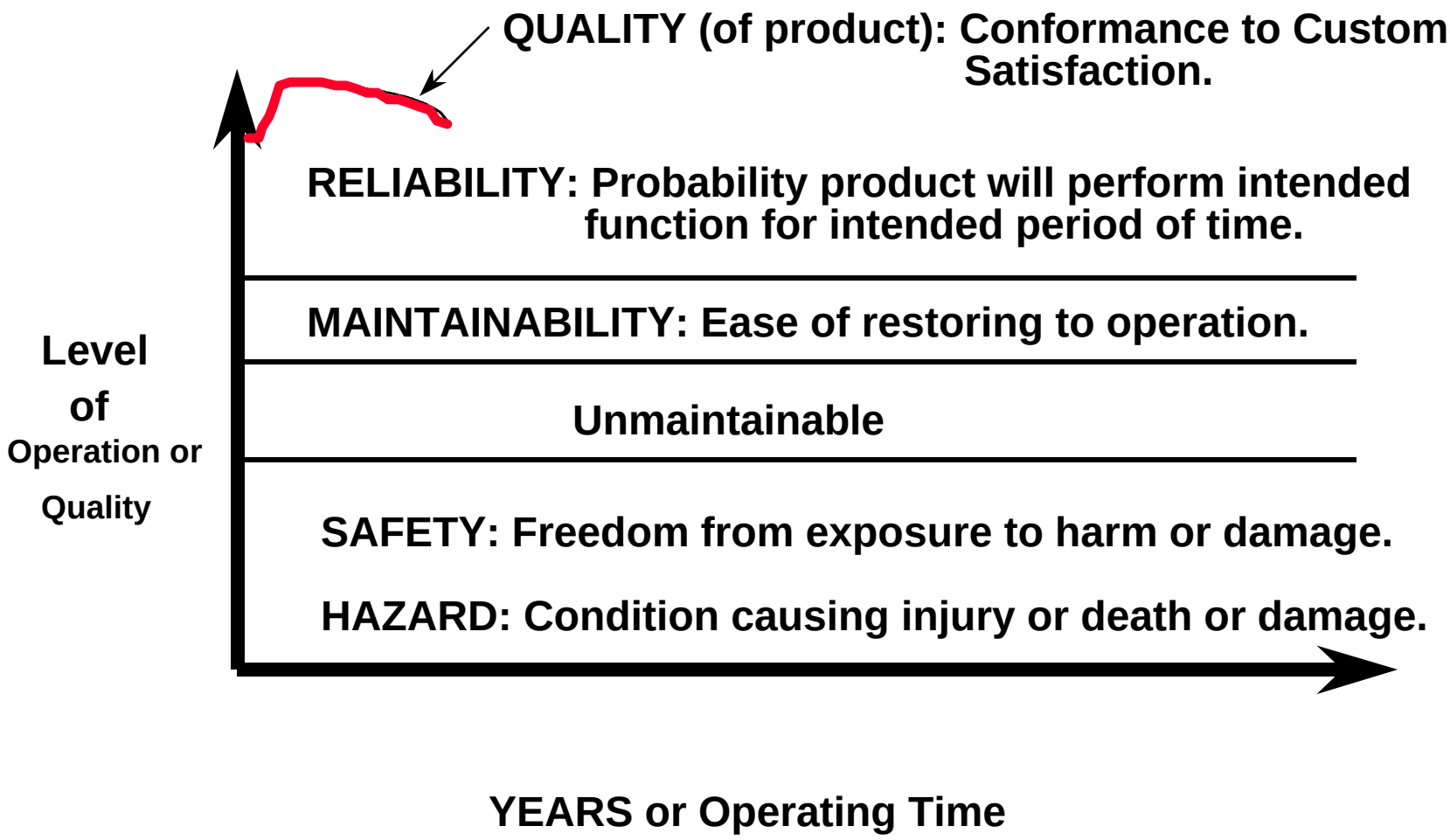
WHAT IS THE RELATIONSHIP BETWEEN:

- **QUALITY**
- **RELIABILITY**
- **SAFETY**

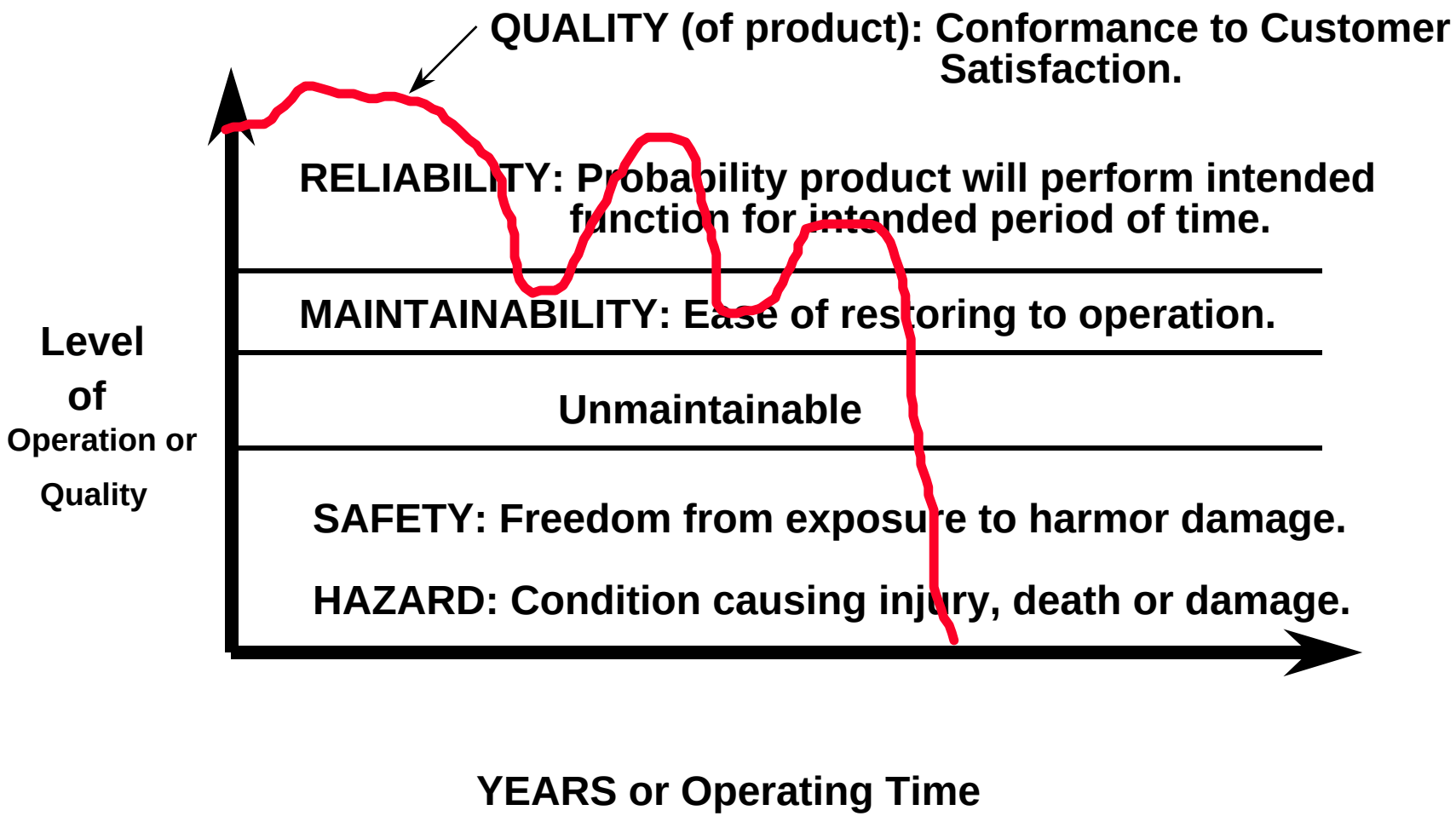




RELATIONSHIP:
QUALITY -- RELIABILITY-- SAFETY



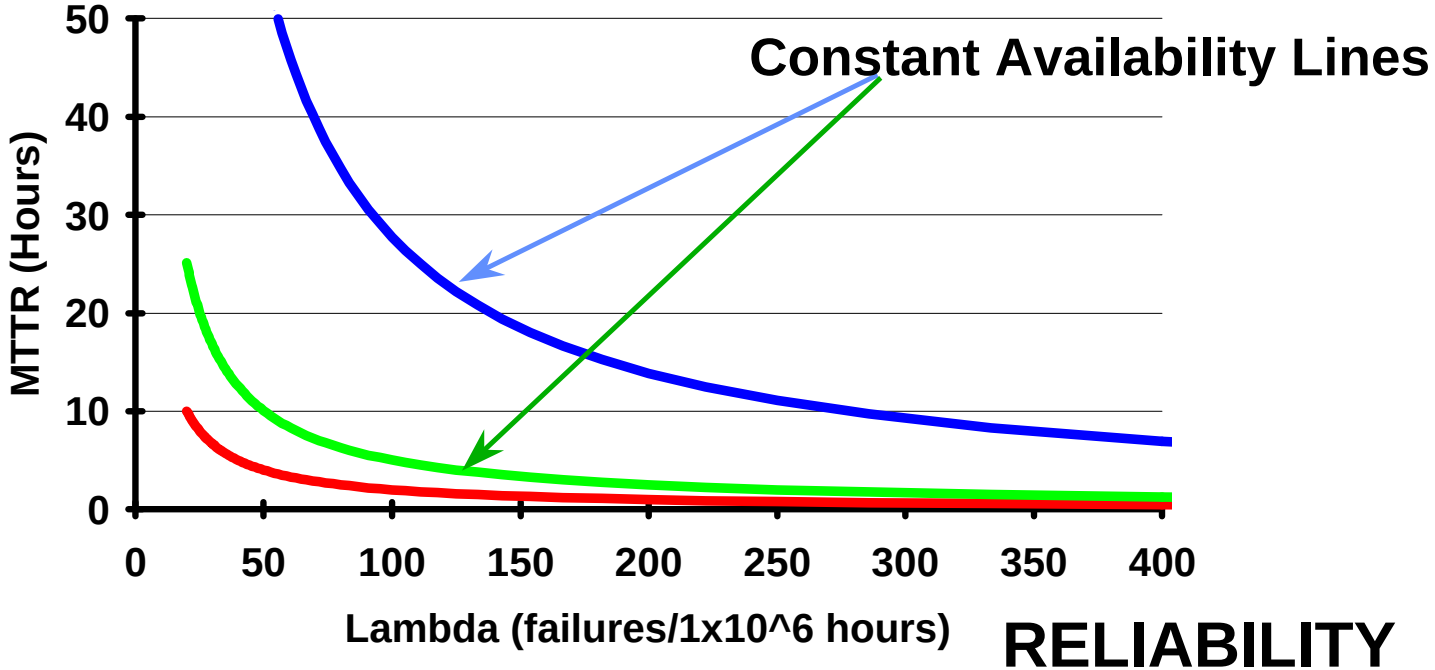
RELATIONSHIP:
QUALITY -- RELIABILITY-- SAFETY



What is the Relationship:
Availability to Reliability to Maintainability?

AVAILABILITY = f (Reliability, Maintainability)

MAINTAINABILITY



RELIABILITY

DR01-25

What Are Various PRACTICES Associated With Mission Assurance?

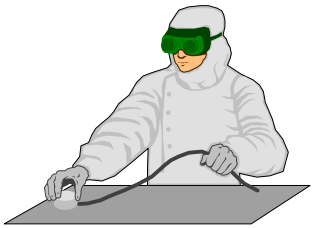
- QUALITY ASSURANCE
- **RELIABILITY ENGINEERING**
- LOGISTICS ENGINEERING
- MAINTAINABILITY ENGINEERING
- SYSTEM SAFETY ANALYSIS
- HUMAN FACTORS ANALYSIS
- SOFTWARE PERFORMANCE
- SYSTEM EFFECTIVENESS

MEASURING RELIABILITY and MORE

- **RELIABILITY INVOLVES MEASURING OR ESTIMATING MISSION SUCCESS.**
- **RELIABILITY MUST ALSO DETERMINE WHY SOMETHING FAILED AND HOW TO IMPROVE PRODUCT LIFE.**
- **RELIABILITY MUST HELP IMPROVE THE DESIGN PROCESS.**
- **RELIABILITY MUST HELP IMPROVE THE MANUFACTURING PROCESS.**

Calculate Reliability, Test Reliability and ...

IMPROVE: (1) To advance to a better state or mission success. (2) To increase the productivity or value of. (3) To make beneficial additions or changes.



Improve Manufacturing Process to INCREASE Reliability

CALCULATE EXISTING RELIABILITY

TEST TO FIND EXISTING RELIABILITY

DR01-28

CONCLUSIONS

- **BENEFITS OF RELIABILITY ENGINEERING INCLUDE:**

Increased knowledge of failures.

Ability to complete missions successfully

Accurate forecast spares, improved availability.

Products that work.

Cost Reduction.

- **RELIABILITY IS:**

  The *probability* that an item can perform its intended function

  for a specified interval

  under stated conditions

CONCLUSIONS+

- **BESIDES MEASURING RELIABILITY, WHAT IS EVEN MORE IMPORTANT?**

Why something fail and how do we improve product life?

Improving the design and manufacturing process through interactions with these activities.

- **WHAT ARE THE SOURCES OF FAILURES?**

Design, Manufacture, Operation

By knowing the sources of failure, (mfg. processes, design problems, "new" operational environment) root cause of failures can be corrected.

END/MORE >> DR01-30

Additional Information

RELIABILITY & LIFE CYCLE COSTS

PROBLEMS--Reliability Programs:

- **"Achieving High Reliability is Expensive."**
  - **new technology.**
  - **complex technology.**
- **"Requires expensive resources."**
  - **trained engineers.**
  - **management.**
  - **test equipment / test hardware.**
- **"Difficult to Justify."**
  - **"Just use good basic design practice."**
  - **"Minimum reliability to placate a customer."**

REALITY--Reliability Programs

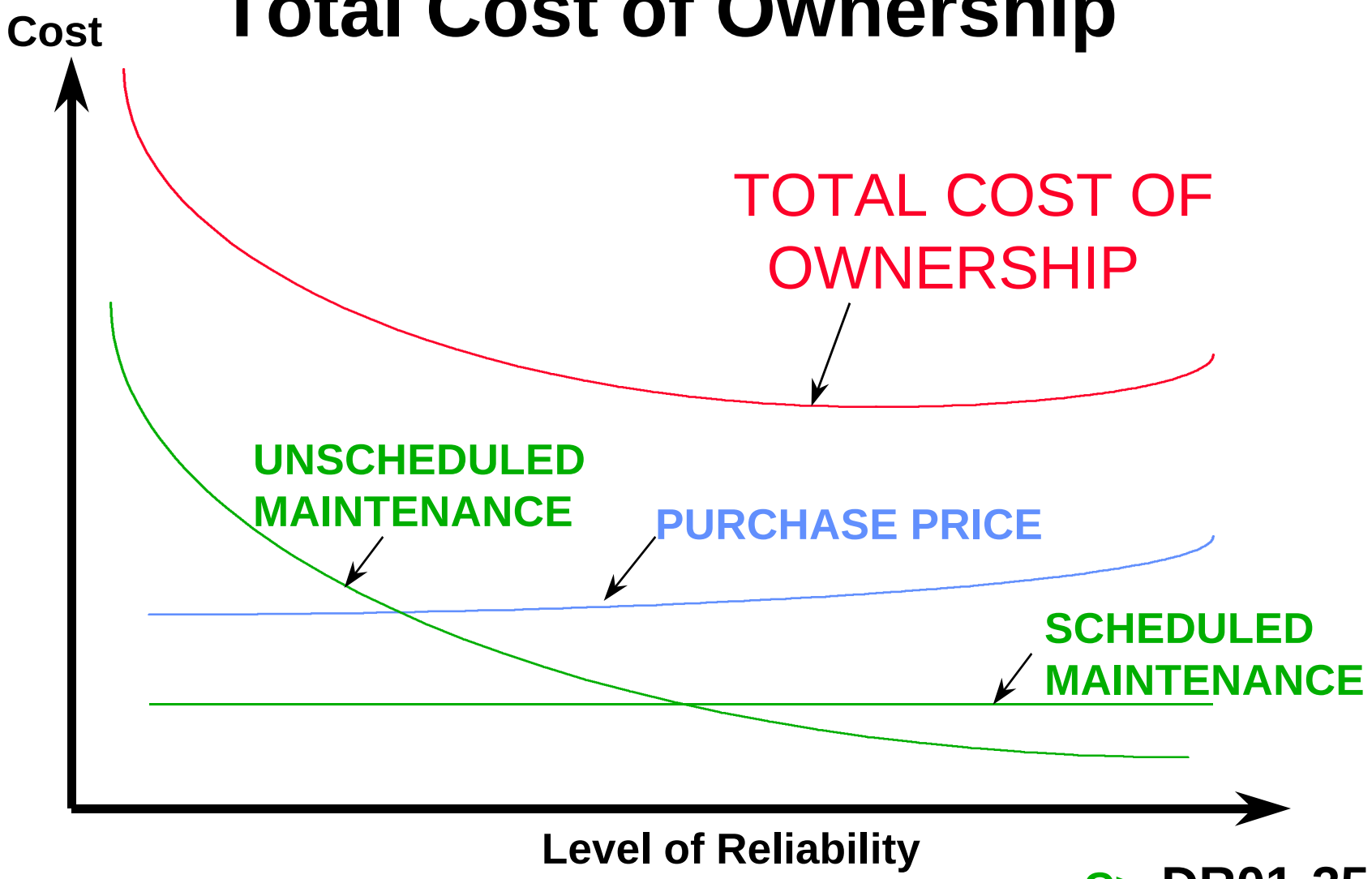
WELL MANAGED RELIABILITY PROGRAMS PAY OFF:

- **Discover failure modes during design & development**
- **Discover mission critical failure modes**
- **Simplify and improve design.**
- **Provide a solid bases for product improvement.**
- **LOWEST TOTAL COST OF OWNERSHIP**

TOTAL COST OF OWNERSHIP

- INITIAL PURCHASE PRICE
- SCHEDULED MAINTENANCE COSTS
- SALVAGE VALUE
- UNSCHEDULED MAINTENANCE COSTS
- COST OF LOST PRODUCTION TIME
- INDIRECT TIME OF UNSCHEDULED MAINT.

Total Cost of Ownership



C> DR01-35

CONCLUSION -- COST OF RELIABILITY

- RELIABILITY COSTS ARE HARD TO QUANTIFY.
- POTENTIAL CUSTOMERS ARE LOOKING AT TOTAL COST OF OWNERSHIP.
- THERE ARE MANY INDIRECT RELIABILITY COSTS:
  - GOODWILL
  - MARKET SHARE
  - PUBLICIZING OF FAILURES
  - EXTREME UNRELIABILITY CAN LEAD TO LITIGATION
  - FAILURES INTERNAL TO PRODUCTION
- A RELIABLE PRODUCT IS USUALLY CHEAPER TO MANUFACTURE.

BASIC RELIABILITY MATH

- **Mean Time Between Failures =** $MTBF$
- **Failure Rate =** $\lambda = 1/MTBF$
- **Reliability* =** $exp\,(-\lambda t)$
- **Mean Time To Repair =** $MTTR$
- $Availability = MTBF/(MTBF + MTTR)$

***Assuming exponential failure rate**

F

BASIC RELIABILITY MATH (con't)

- **Five pressure transducers (model c-4) were tested and they were found to fail after an average 2257 hours. Time studies have shown it takes 5.5 hours to diagnose, remove, replace and check out a unit.**
- **Assuming continuous use and an exponential failure rate, what is the MTBF, the failure rate, the reliability for a mission of 50 hours in length, and the availability.**
- **MTBF = 2257 hours.**

λ = 1/MTBF = 1/ _____ = _____

Reliability = exp(-λt) = exp (- _____x_____) = _____

Availability = MTBF/(MTBF + MTTR)

_____/(_____+_____) = _____

F

BASIC RELIABILITY MATH (con't)

- **Five RTD temperature sensors, (model RTD-A-7) were tested and they were found to fail after an average 4026 hours. Time studies have shown it takes 52 hours to diagnose, remove, order, receive, replace and check out a unit.**
- **Assuming continuous use and an exponential failure rate, what is the MTBF, the failure rate, the reliability for a mission of 50 hours in length, and the availability.**
- **MTBF = 4026 hours.**

λ = 1/MTBF = 1/ _____ = _____

Reliability = exp(-λt) = exp (- _____x_____) = _____

Availability = MTBF/(MTBF + MTTR)

_____/(_____+_____) = _____

What are the DEFINITIONS?

- **FAILURE--**
- **FAILURE ANALYSIS--**
- **HAZARD--**
- **QUALITY--**
- **QUALITY ASSURANCE--**
- **RELIABILITY ENGINEERING--**
- **SAFETY--**
- **SAFETY ANALYSIS--**